Radiation Effects Facility
Cyclotron Institute
Texas A&M University

SEUSS

CONTROL SOFTWARE TUTORIAL

(Written by Vladimir Horvat - updated on March 22, 2024)

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1. ABOUT SEUSS

SEUSS is the name of the software package that we, at the Radiation Effects Facility, run in order to characterize the beam used for radiation testing, to position of the device under test, and to control exposure of the device to the beam. The software documents the settings, logs, with time stamps, all the actions taken as well as their outcomes, and produces a report for each run as well as the summary report that includes the data from all runs.

SEUSS is written for Microsoft Windows™ operating systems and has graphical users interface (GUI) typical of the Microsoft Foundation Class Library (MFC) applications.

2. PROGRAMMING GOALS AND PRINCIPLES

The goal was to make the software easy to use and intuitive as much as possible. Programs in the SEUSS package have no menus to go through in order to activate the desired feature. Most of the features can be activated by a single click of the mouse and the need to use the keyboard is minimized. Buttons and boxes are labeled in plain English and those that are not available in the given context are typically disabled or hidden. Guidance via pop-up message boxes is provided for the procedures that require more than a single step.

At the Cyclotron Institute's Radiation Effects Facility our SEUSS software controls the installed hardware components using dedicated drivers and dynamic link libraries (DLL's). That software can also be set to ignore the hardware and run in simulation mode. However, simulation mode is also needed to run the software on the computers that do not have the drivers and DLL's installed. To avoid the need to install the drivers and the DLL's on off-line computers, a separate set of inactive SEUSS programs is available. These programs have the same names and the same features as their active (hardware-controlling) counterparts, but they are built from codes in which the lines that address the hardware are eliminated. This way our users can run SEUSS software on their own computers and become familiar with it before arriving on site.

3. PROGRAM INSTALLATION

SEUSS software is designed for Microsoft Windows™ operating systems starting with Windows 7. Because of the size of the application windows, the screen resolution should be at least 1024 pixels × 768 pixels.

For 64-bit machines the files necessary to install and run the software are contained in the archive SEUSS-64.zip that can be downloaded at

http://cyclotron.tamu.edu/vladimir/SEUSS-64.zip .

Files can be extracted from the archive using any program designed for that purpose (such as 7-Zip, which may be included with your version of Windows operating system) or the original WinZip program that can be downloaded at

http://www.winzip.com .

The extracted files should be placed in any chosen EMPTY folder. This folder will be referred to as the SEUSS folder. To run the program, find the file SeussW.exe using Windows Explorer and double-click it. For convenience, a shortcut to this file can be made and placed on the Desktop or in any other folder of your choice.

A separate version of the same software is available for 32-bit machines. The corresponding archive can be downloaded at

http://cyclotron.tamu.edu/vladimir/SEUSS-32.zip .

The latest version of the software is not compatible with Windows XP operating system, However, the previous (2023) version of the software is. For a limited time this version will be available for download at

http://cyclotron.tamu.edu/vladimir/SeussW.zip .

This version of the software will also run on operating systems as recent as Windows 12. It will not be in conflict with another version of SEUSS on the same computer, as long as it is installed in a separate folder.

4. RUNNING SEUSS

4.1. Opening the main application window

The screenshot in Figure 1 shows an example of the main application window, which will be referred to as the SEUSS window. It will open when you start program SeussW.exe located in the SEUSS folder.

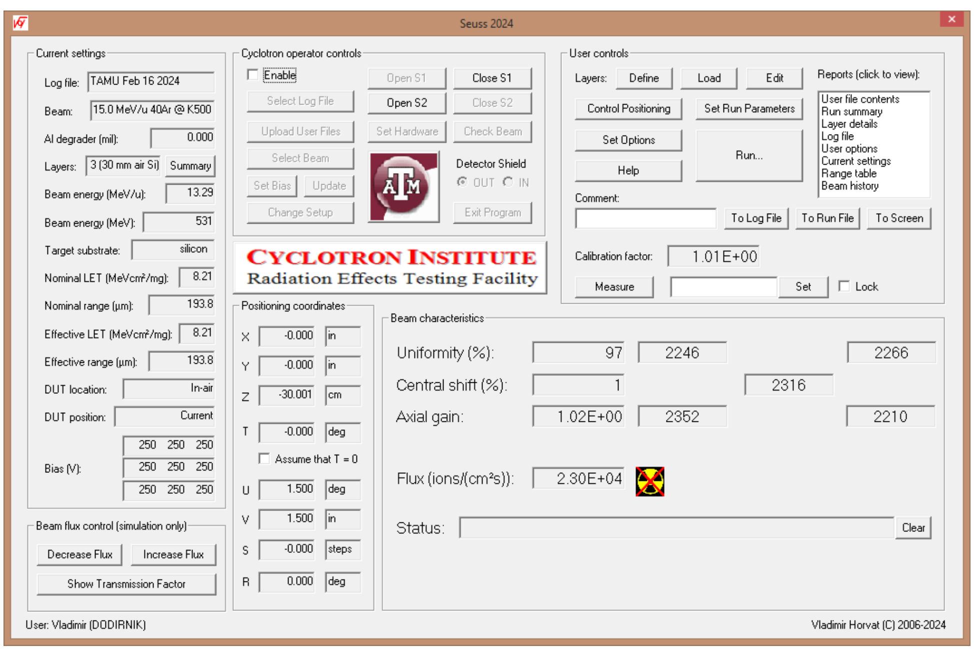

Figure 1. Example of the main application window (a.k.a. the SEUSS window) from the 2024 release. In the previous or subsequent releases of the software the SEUSS window may have a slightly different layout and contain some different features.

The SEUSS window features displays and controls grouped by their usage and functionality. The functions of these components are described individually in the linked hypertext documents included in the installation archive, starting with SeussW.htm, which can be opened with any installed internet browser program. The default browser will start by double-clicking SeussW.htm from within Windows Explorer. The Help button in the SEUSS window is set to do the same. Alternatively, the help pages can be accessed from our server, starting at

http://mare.cyclotron.tamu.edu/vladimir/SeussW.htm .

On the other hand, this tutorial describes in basic terms the most common *usage* of the program in a typical chronological order. Familiarity with or intuitiveness of the MFC GUI is assumed.

4.2. Specifying the log file

Program SEUSS logs all the actions that it takes on user's request as well as their outcomes, along with the associated dates and times. The default file in which the program writes these records (named CI-TAMU Feb 2020.) is set up at the time of program installation. If several users take turns running the program on the same computer (which is the case at the Radiation Effects Facility), each user should have their own log file, which can be selected (if it already exists) or created (if it does not exist yet) using the Select Log File button in the Cyclotron operator controls group. An example of the dialog box that opens is shown in Figure 2. The SEUSS window will be temporarily closed while the Select Log File dialog box is open. A copy of a listed log file can be viewed by selecting the file and clicking the Browse selected button. Even though any log file name can be selected, a name consisting of the users' company name followed by the current month, day and year is a typical choice.

From the SEUSS window the contents of the currently selected log file can be viewed by clicking Log file in the Reports list of the User controls group, while the current log file name is displayed in the top-row box of the Current settings group.

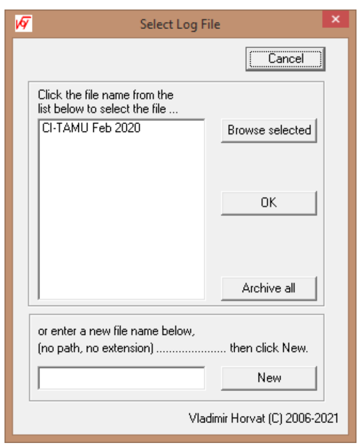

Figure 2. Example of the Select Log File dialog box.

To enable the buttons in the Cyclotron operator controls group the Enable box must checked. Note that this will disable the User controls group until the Enable box is un-checked.

In order to keep the program installation as simple as possible, the log file and all the other files that are prepared for the users or by the users are stored in the SEUSS folder. However, at the Radiation Effects Facility these files are stored in the Users subfolder. This helps prevent accidental removal of files that SEUSS needs in order to run properly.

4.3. Setting the operating conditions

The SEUSS window contains a group named Cyclotron operator controls. At the Radiation Effects Facility (referred to as "our facility" in the text that follows) controls located in this group are used by the cyclotron operator. Users are generally discouraged from using these controls and are expected to notify the cyclotron operator if they intend to use them. However, a user running SEUSS in the simulation mode should use the controls in this group to specify the desired operating conditions or to exit the program.

Specifying the operating conditions includes choosing the cyclotron to be used (K150 or K500), choosing the cyclotron beam and setting the beam flux, selecting the target location (vacuum chamber or in-air setup), and defining the target composition. The target is typically referred to as the "device under test (DUT)" or just "device".

4.3.1. Specifying the cyclotron and the target location

The choice between the K150 and K500 cyclotron implies a different selection of available beams, although some beams are available on both machines. Also, while in-air setup is available at the end of the dedicated beamline from either cyclotron, a vacuum chamber is available only at the K500 beamline. For practical reasons, the positioning hardware is slightly different at each of the three possible target locations, and so by choosing the target location the user lets the program select the appropriate set of hardware parameters.

Upon clicking the Change Setup button, the SEUSS window is replaced by the Change Setup dialog box, in which radio buttons can be used to select between the K150 and the K500 cyclotron, and between the in-air setup and the vacuum chamber. Figure 3 shows an example of the Change Setup dialog box, with the cyclotron selection and the target location selection set by default at the time of program installation. If these settings are changed, the new selections become default. An off-line user may ignore the numerical data and close all the pop-up windows associated with the change of setup.

Close the Change Setup dialog box by clicking the OK (or Cancel) button and the SEUSS window will re-open. The target location will be displayed in the 12th-row box of the Current settings group, while the selected cyclotron will be indicated in the 2nd-row box of the same group, on the far left. The two of them are now the default parameters.

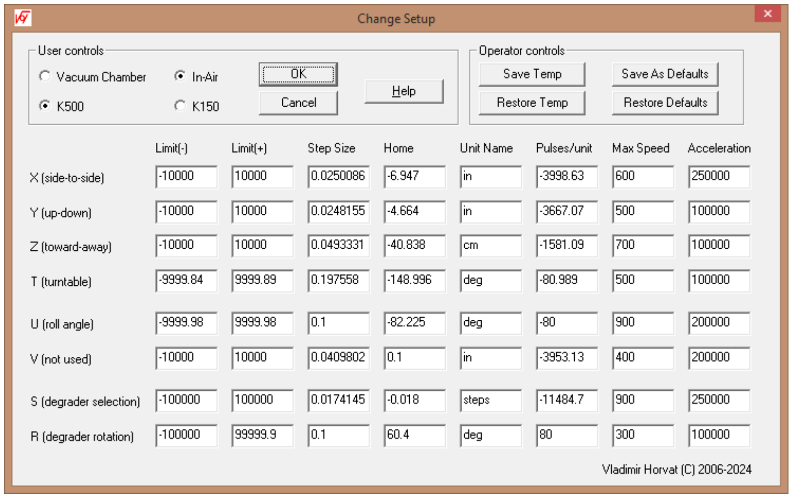

Figure 3. Example of the Change Setup dialog box (from the 2024 release).

4.3.2. Specifying the beam

Upon clicking the Select Beam button in the Cyclotron operator controls group, the SEUSS window is replaced by the Select Beam dialog box (shown in Figures 4 and 5), in which radio buttons can be used to select the desired beam.

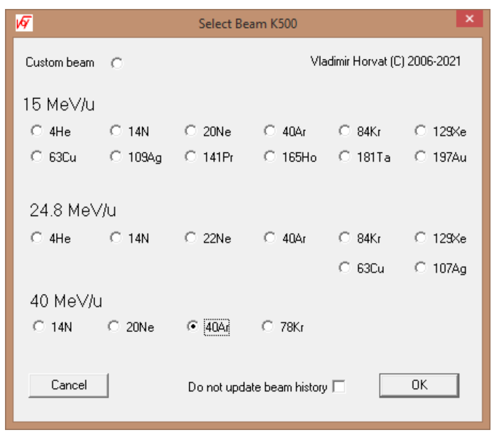

Figure 4. Example of the Select Beam dialog box for the K500 cyclotron.

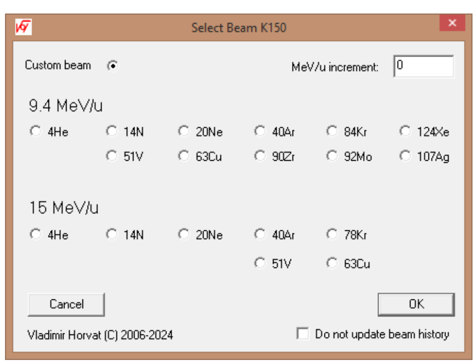

Figure 5. Example of the Select Beam dialog box for the K150 cyclotron.

If the desired beam is not listed specifically, then Custom beam should be selected. In that case clicking the OK button opens the Custom Beam dialog box (shown in Figure 6), in which the beam parameters can be specified. If you want to use the Search button feature, note that chemical symbols are capitalized while element names are not.

Upon clicking the OK (or Cancel) button in either of the three beam-selecting dialog boxes after making the final beam selection, that dialog box will close and the SEUSS window will re-open. The Beam box in the Current settings group will show the selected beam (and the chosen cyclotron). This is now the default parameter.

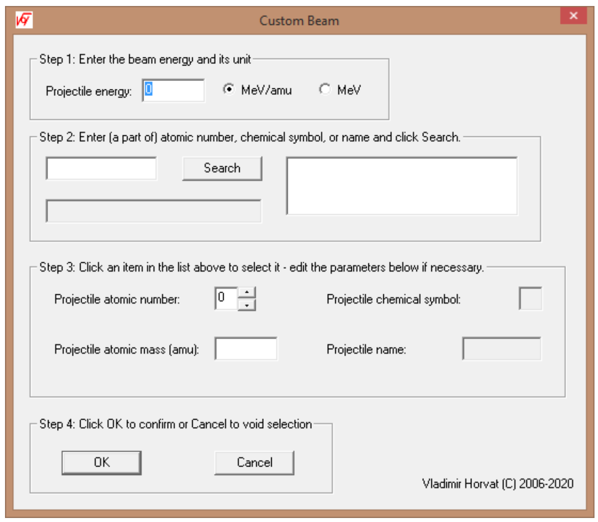

Figure 6. Example of the Custom Beam dialog box.

4.3.3. Setting the beam flux

At our facility the beam flux (referred to as "flux" in the text that follows) is set by the cyclotron operator at the request from the users. However, a user running SEUSS in the simulation mode sets the desired average flux using the controls located in the Beam flux control group. These controls emulate the mode of flux control at our facility, where the maximum available flux can be reduced to a lesser value by inserting an appropriate set of attenuators. Available attenuators have transmission factors of 1/3, 1/10, 1/100, and 1/1000. They can be combined in order to easily reduce the flux by a factor of 3, 10, 30, 100, 300, 1000, *etc*., up to 3E6. Other methods are used for fine-tuning of the flux to other values, if needed. Off-line users can increase or decrease the simulated average flux one step at a time by clicking the Increase or Decrease button in the Beam flux control group. Upon clicking the Show Transmission Factor button, a window pops up to display the requested information. At the time of program installation the transmission factor is set to 3E-5. If this setting is changed, the new selection becomes default.

Flux values are repeatedly measured over one-second intervals and the results are shown in the Flux box located in the Beam characteristics group. When the flux is very low, variations of the displayed values may seem large. While flux may vary as a function of time, these variations are typically due to the expected statistical fluctuations and are not necessarily an indication of beam instability.

4.3.4. Defining the target composition

A typical user wants to know energy and LET of the beam as it hits the substrate of the device under test. SEUSS provides that information accurately once the user prepares an ordered list of all the layers of materials that the beam goes through on its way to the substrate, as well as the mass thicknesses (or linear thicknesses and densities) of these layers. For the in-air target locations this list also includes the air and the foil that separates the beamline vacuum from the atmosphere (referred to as the "vacuum window" in the text that follows). The substrate must be specified as well.

The prepared list of layers must follow a certain format and be saved in a named layer file with extension .lay. The layers must be specified in the upstream order, starting with the substrate. Regardless of its actual thickness, the substrate must be specified as having zero thickness.

Most users have DUTs with exposed silicon substrate, in which case the list of materials for targets in a vacuum chamber includes only one layer (silicon substrate). A layer file for this case (named Bare silicon.lay) is readily available and can be loaded by clicking the Load button in the User controls group. Once the file is loaded, the information contained in it becomes default.

For targets in air, the layer file must include the air and the vacuum window material, along with their mass thicknesses. An aluminum vacuum window is used for runs with proton beams at the K150 cyclotron, while in all other cases the vacuum window is made of aramica aramid. Standard thickness of the aramica foil on a 1" diam. window is 1 mil (25.4 µm). Bigger windows (1.5" diam. and 1.75" diam.) are made of 38 µm thick aramica foil. Also available is a 0.75" diam. window with a 16 µm thick aramica foil. Teonex™ foil may be used instead of aramica in the future. Collimators of various aperture shapes and sizes (circular and rectangular) are available for use with any available window. They are made thick enough to stop any of our heavy-ion beams. For a typical proton beam a pair of collimators should be used to ensure that the beam is stopped.

The air gap should be physically set to be as small as possible. For convenience, the air gap may be adjusted to round it up to the nearest full centimeter. If a DUT will be irradiated by the beam at angles of incidence other than zero degrees (*i.e.*, other than at normal incidence), it is convenient to minimize the average air gap at the largest angle and then keep the same average gap for all the other angles. This way it will not be necessary to load a different layer file whenever the angle of incidence is changed.

At our facility the air gap can be easily measured with a built-in laser pointer attached to the sliding arm of a position decoder (see 3.4.5.) .

Ten layer files for DUTs with exposed silicon substrates in air are readily available and can be loaded using the Load Layers dialog box, which opens upon clicking the Load button in the User controls group. An example of the Load Layers dialog box is shown in Figure 7. The supplied layer files correspond to the standard aramica foil thickness of 1 mil and air gaps of 10, 20, 30, 40, 50, 60, 70, 80, and 90 mm. They are named xx mm air Si.lay, where xx is the air gap in mm. Once a layer file is loaded, the information contained in it becomes default.

Any one of the readily available layer files can be edited (using the Edit button in the User controls group) to specify a different air gap and/or a different aramica foil thickness. An example of the Edit Layers dialog box that opens is shown in Figure 8. You must specify an unused layer file name to save the changes and make them effective. Once the file is saved, the information contained in it becomes default. It is recommended that you pick a file name that starts with a unique identifier (like abbreviated name of your company). This will make it easier for you to find and identify your files and make it less likely that you will unintentionally use someone else's file.

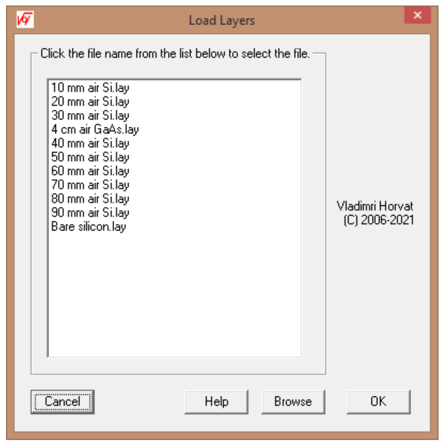

Figure 7. Example of the Load Layers dialog box.

Note that you cannot use this procedure to add a layer or to delete one, although in the latter case you could work around this by specifying an extremely small thickness (not recommended). You should specify the unit of thickness before entering the thickness value. Changing the unit after the amount is entered will trigger unit conversion, *i.e.*, the entered amount will be modified to counteract the unit change and keep the thickness value unchanged. Note that SEUSS contains densities of the materials in its database, so that either linear thicknesses (in µm, mm, cm, mil) or mass thicknesses (in mg/cm^2) can be specified. (Mass thickness is a product of linear thickness and density.)

If a suitable layer file cannot be prepared using Load and/or Edit button functions, it has to be built from scratch using the Define Layers dialog box, which opens when Define button in the User controls group is clicked. An example of the Define Layers dialog box is shown in Figure 9. This method lets you specify up to 100 layers, starting with the substrate as the first layer (Layer 0). The substrate must have thickness value of zero. For each layer you can specify composition using the included database of elemental substances and common compounds or mixtures. You can even define a substance that is not in the database. For practical purposes the elemental composition list is limited to 8 items or less.

Keep in mind that all DUT layers rotate with the DUT and should be specified as rotating using the check box on the top right. The air and the vacuum window do not rotate with the DUT, and so this box has to be unchecked for their corresponding layers. Status of this check box has no effect if all the measurements are done at normal incidence.

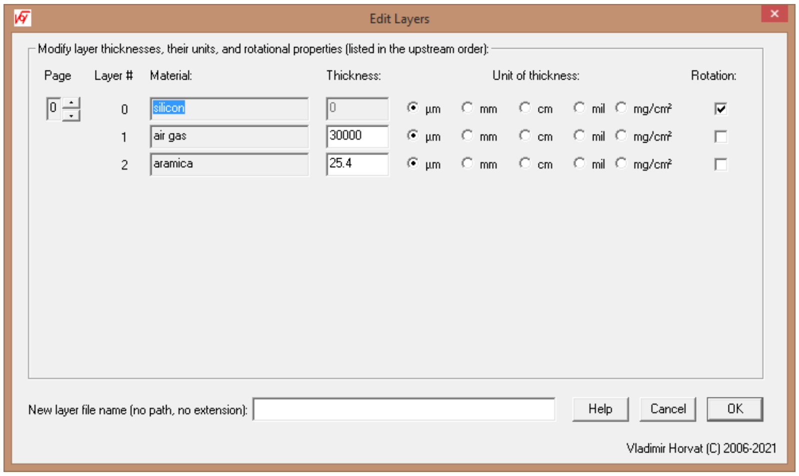

Figure 8. Example of the Edit Layers dialog box.

An unused file name must be specified after the last layer in order to save the layer information and make if effective. Once the file is saved, the information contained in it becomes default. It is recommended that you pick a file name that starts with a unique identifier (like abbreviated name of your company). This will make it easier for you to find and identify your files and make it less likely that you will unintentionally use someone else's file.

Layer information can be checked at two levels of detail. To see only a list of layer names, thicknesses, and rotation statuses, click the Summary button in the Current settings group. The Layers box next to the Summary button shows the total number of layers followed by the corresponding file name enclosed in parentheses. To see the detailed annotated list of parameters for each layer, click Layer details in the Reports list located within the User controls group.

Users can prepare their layer files before arriving on site, save them on a compatible USB memory stick and upload them at the beginning of their scheduled run. To accomplish this, the USB stick must be plugged into the USB port located on the SEUSS monitor inside the Data Room. Once the USB stick is recognized by the operating system, the files must be copied to E:\Uploads. In the SEUSS window the Enable box must be checked and then the Upload User Files button must be clicked in order to move the layer files to the appropriate folder on the SEUSS computer.

4.4. Positioning the target and controlling the beam parameters

When the Control Positioning button in the SEUSS window is clicked, a dialog box similar to that shown in Figure 10 opens. Note that its Current settings group is identical to the one in the SEUSS window, with the Bias row omitted.

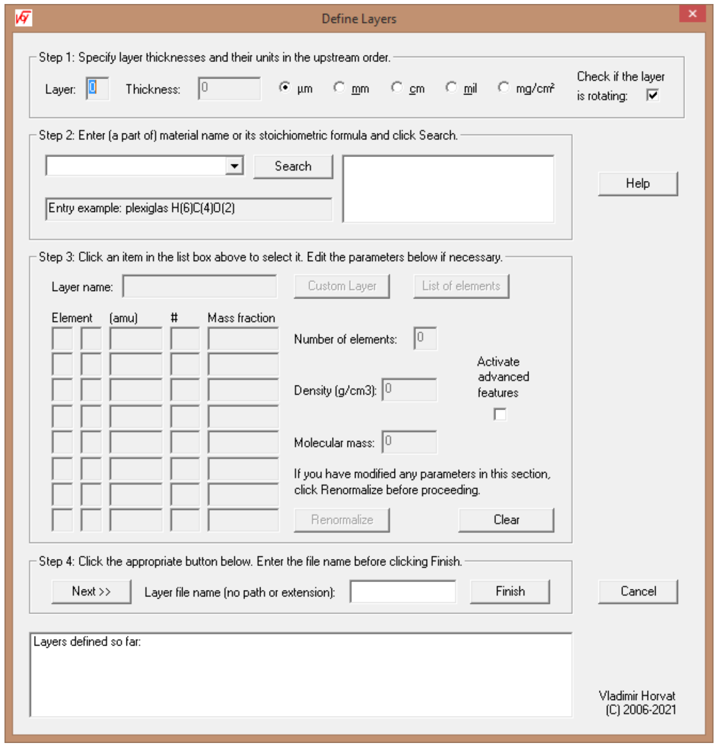

Figure 9. Example of the Define Layers dialog box.

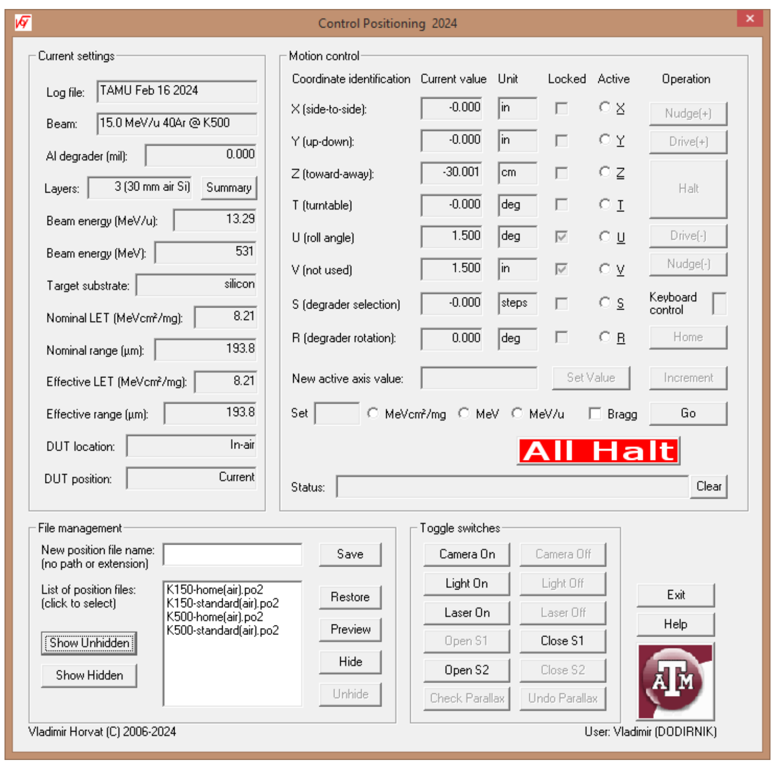

Figure 10. Example of the Control Positioning dialog box.

4.4.1. DUT mounting and positioning (on-site)

The devices to be tested (*i.e*., the targets) can be properly positioned using SEUSS when they are firmly attached to the turntable (platter) that is a part of our facility's positioning system. Targets with their supporting structures may be attached to the platter directly or they may be mounted on one of the provided frames or be held by a provided vise. Note that in order to prevent possible damage to the limit switches, target fixtures may not be attached to the platter using C-clamps.

The Camera On button in the Toggle switches group can be used to turn on the camera located inside the beamline, behind the vacuum window. The camera is hooked up to a nearby monitor, so that the position and the motion of the target can be viewed from the beam perspective, provided that the vacuum window is made of a transparent material, such as aramica. Note that the protective cap at the end of the beamline must be taken off for this to work. Make sure that the cap is back on whenever you don't need it to be off.

Moving the target to a new position should always be done with a person physically present near the target, who will stop the motion in the case of an emergency, *i.e*., if a moving part is about to touch the fragile vacuum window or some other fixed surface, if a cable attached to a moving part does not have enough slack, if something is caught in the motion mechanism, *etc*. An emergency push-button conveniently located nearby can be used to almost instantly cut the power to all the motors. The power can be restored only by the cyclotron operator.

When high-flux beams of protons from the K150 cyclotron are used, the vacuum window must be made of aluminum, which is not transparent. Centering of the target then relies on a projected laser-beam crosshair. When K150 cyclotron is selected, the buttons in the bottom row in the Toggle switches group are relabeled and repurposed to turn the crosshair on and off.

4.4.2. Motion controls

The intended axis of motion (X, Y, Z, T, U, V, S, or R) is selected using the appropriately labeled radio button in the Motion control group. When one is selected, the associated motion control buttons on the far right become available. When Drive(+) or Drive(-) button is clicked, the motion starts along the selected axis in the positive or negative direction, respectively. (The direction assignments are indicated on the labels attached to the corresponding elements of the positioning stage.) The motion stops when the Halt button is clicked.

Hitting the space bar on the keyboard acts the same way as clicking the Halt button, provided that the cursor stays inside the Keyboard control box (where it is automatically placed by default whenever motion starts). Likewise, functions of the Drive(+) or Drive(-) buttons can be initialized by the arrow keys on the numerical keypad provided that Num Lock is on (sic!). Up or Right arrow (numerical pad 8 and 6) can be used for + direction, while Down or Left arrow (numerical pad 2 and 4) can be used for - direction. Positioning using keyboard is convenient whenever eyes must be kept on the target itself.

Even if motion is in progress along one axis, another motion can be started along a different axis. However, clicking the Halt button will stop the motion along the most recently selected axis only. To stop all motion click the red All Halt button.

Nudge(+) and Nudge(-) buttons are used to fine-tune the final position. They initialize motion along the selected axis only by one small step at a time. The same effect can be produced by the + and - keys on the numerical keypad of the keyboard. The default step sizes can be defined using the function of the Change Setup button located in the Cyclotron operator controls group in the SEUSS window. Normally the step sizes are not the smallest possible steps.

Position along a selected axes can be set by specifying the desired coordinate value in the New active axis value box and clicking Set Value. This is typically done to set the DUT angle with respect to the beam axis. By entering a value in the New active axis value box and clicking the Increment button, the coordinate along the selected axis will change to the sum of the previous value and the entered value.

A Locked check box is used to enable or disable motion along the corresponding axis. Checking Locked box is recommended if no motion along the corresponding axis is intended.

Note that when the DUT is inside the vacuum chamber, X and Y are the horizontal and vertical axes in the mounting-frame plane, while the Z axis is horizontal and perpendicular to the mounting frame. When the DUT is in air, Z axis is along the ion beam axis, while X and Y are the horizontal and vertical, respectively, both being perpendicular to Z.

In the "Vacuum chamber" setup coordinates U and V specify the aperture of the horizontal and vertical slits, respectively. In the "In-air" setup coordinate V is unused , while coordinate U specifies the DUT roll angle. Roll angle control requires additional hardware that will be installed on user's request in advance. It is seldom used.

4.4.3. Saving and restoring DUT positions - purpose of the Home *button*

The currently set DUT position can be saved so that it can be automatically restored on demand at a later time. To ensure reproducibility, the positioning system must not be disturbed in the meantime. Examples of critical disturbances include rebooting of the SEUSS computer, physically changing the position or shape of the system hardware, physically blocking or countering the motion in progress, exceeding the weight limit of the equipment on the platter, *etc*. If such a disturbance occurs, each affected axis has to be re-calibrated, after making sure that the disturbance is no longer affecting it. This is done by selecting the axis and clicking the Home button to initiate travel all the way to the designated limit switch. Make sure that cables attached to the setup have enough slack or else unplug the cables or detach the setup from the positioning system entirely.

It should be noted that only the first four or five axes of motion actually affect the position of the target in vacuum or in air, respectively. For a target in vacuum, axes U and V are used to control aperture of the horizontal and vertical slits, respectively. For a target in air, U is used to control the roll angle, provided that the required hardware is in place, while V is unused. The remaining two axes (S and R) are used to position the degraders in order to control energy of the ions (and indirectly their LET and range). Nevertheless, all eight axes are controlled by the same hardware and all eight associated coordinates are used to characterize the current position.

To save the current position, an unused file name (without path and without extension) must be entered in the New position file name box of the File management group. Then click the Save button. The new position name will appear in the List of position files, assuming that the list is set to show unhidden files. Also, the DUT position displayed in the Current settings group will show the name of the file (without the extension). It is recommended that you pick a file name that starts with a unique identifier (like abbreviated name of your company). This will make it easier for you to find and identify your files and make it less likely that you will unintentionally use someone else's file.

To restore a previously saved position, a file from the list of unhidden or hidden position files has to be selected by clicking its name. Once the selection is confirmed, click the Restore button. Note that Restore function will NOT affect axes that are currently locked. Once the positions along the remaining axes are set, all eight coordinates will be compared to the values from the selected position file. If one or more mismatches are found, the DUT position displayed in the Current settings group will read Current. You may save the current position again to name it otherwise.

The files from the List of position files in the File management group can be unhidden (shown by default every time the Control Positioning dialog box opens) or hidden (shown when the Show Hidden button is clicked). Clicking the Show Unhidden button will display the list of unhidden files again. Other than that, the two lists have the same functionality. This feature may be useful when two groups of users run by taking turns and want to keep their position files separated in order to help avoid confusion. A file from one list can be transferred to the other list by clicking its name to select it and then clicking Hide or Unhide button as appropriate (*i.e.*, whichever is currently enabled). The file can be brought back to the original list using the same procedure.

In order to help restore a position safely, the positioning system will start by moving in the negative Z direction (away from the fragile vacuum window). The remaining coordinates will be set once the target is at a safe distance from the vacuum window. The Z coordinate will be finalized last. Note that this safety maneuver will be bypassed if Z axis is locked. In that case it is the user's responsibility to make sure that restoring of the saved positions does not compromise integrity of the vacuum window. If the window breaks, the system downtime can be substantial and the damage repairs can be very expensive.

To check the values of the saved coordinates, select the position file from the List of position files and then click the Preview button.

Users can save their position files on a compatible USB memory stick so they can use them on their next visit to our facility. To upload the position files the USB stick must be plugged into the USB port located on the SEUSS monitor inside the Data Room. Once the USB stick is recognized by the operating system, the files must be copied to E:\Uploads. In the SEUSS window the Enable box must be checked and then the Upload User Files button must be clicked in order to move the position files to the appropriate folder on the SEUSS computer. Please pick unique names for your position files to avoid overwriting someone else's files in this process. Also, please check all of the positions recorded in the uploaded files by watching them being Restore-d.

4.4.4. Controlling the beam parameters using degraders

Axes S and R are used to select an appropriate aluminum degrader and tilt it in order to control energy of the ions in the beam (and indirectly their LET and range). S coordinate specifies the selected degrader and has to have a positive integer value or zero. R is the tilt angle of the selected degrader. When S is zero, the beam is not degraded and the value of R is irrelevant. Otherwise, effective thickness of the selected degrader in mil (1/1000 in.) is $2^{S-1} / \cos(R)$. Values of R greater than 60° are not recommended because they result in large uncertainty of the degrader effective thickness. They can be avoided by increasing S (*i.e.*, by using a nominally thicker degrader). At the K500 beamline setup the maximum value of S is 9, which corresponds to the degrader thickness of 256 mil or its effective thickness of 512 mil at R = 60°. At the K150 beamline setup the maximum value of S is 6, which corresponds to the degrader thickness of 32 mil or its effective thickness of 64 mil at R = 60°.

However, the degraders are seldom selected and tilted directly. For the most common applications the software will determine the required degrader thickness and set S and R accordingly. The three radio buttons at the bottom of the Motion control group are used to select whether the degrader should be set to control the LET (in MeV cm^2 / mg), energy (in MeV) or energy per nucleon (in MeV/u) of the ions in the beam. The associated value (in the corresponding units) is then entered in the Set box. Click the Go button to start the calculations and be prompted for setting the degraders accordingly. To degrade the beam down to the Bragg peak, check the Bragg box and click Go. All this will work even if S and R are locked. In fact, keeping S and R locked is recommended, so that their value does not unintentionally change whenever a position is restored. However, to select undegraded beam, you should unlock S and R and set them to 0, then lock them again.

Once the degrader is set, the information in the Current settings group will be updated. Note that coordinate T also has an effect on these values. If T is changed to a different value, the beam parameters will be recalculated and their values will be updated.

Degrading the beam energy below the Bragg-peak value is possible, but it is also strongly discouraged. One reason is that below the Bragg-peak the LET value of the beam drops down to zero within a very short distance, which makes it very uncertain. Another reason is technical in nature. Namely, at low beam energies the signals produced by the ions in our detectors (located downstream from the degraders) could be at, below, or above but too close to the noise level, which could result in inaccurate dosimetry. This problem can be mitigated by putting a degrader foil of suitable thickness downstream from the detectors. That degrader foil then must be included in the layer file(s).

4.4.5. Toggle switches

The Camera On button in the Toggle switches group can be used to turn on the camera located inside the beamline, behind the vacuum window. The camera is hooked up to a nearby monitor, so that the position and the motion of the target can be viewed from the beam perspective, provided that the vacuum window is made of a transparent material, such as aramica. Note that the protective cap at the end of the beamline must be taken off for this to work. Make sure that the cap is back on whenever you don't need it to be off. The Camera Off button in the Toggle switches group can be used to turn off the camera. Note that the camera will be turned on automatically whenever a motion is started and will be turned off automatically 30 seconds after the last time it was instructed to be turned on. The latter is set up in order to help prevent overheating of the camera under vacuum. The camera is tied to the downstream side of the downstream shutter S2, so that it is out of the way of the beam during a run.

The Light On button in the Toggle switches group can be used to turn on the light bulb located in the vacuum chamber. This makes it possible to see the target when it is located in the darkness of the vacuum chamber. There is no point in using this feature when the target is outside the vacuum chamber.

The Laser On and Laser Off buttons, respectively, can be used to turn on and turn off a downward-pointed laser beam. The laser pointer is mounted on a horizontal sliding arm positioned directly above the beamline. Horizontal position of the sliding arm is decoded and digitally displayed by a device surrounding the arm. The displayed position is expressed in millimeters. The purpose of this setup is to facilitate measuring the air gap between the vacuum window and the surface of the device under test. Once the laser is turned on, the moving arm is slid so that the laser beam points at the vacuum window position. At this point the displayed position Z_1 must be noted.

Next, the moving arm is slid so that the laser beam points at the position of the target's front surface. The air gap is then calculated as $Z_2 - Z_1$, where Z_2 is the currently displayed position. To set the air gap to a desired value *D*, the arm is positioned so that $Z_2 = D + Z_1$ and then the target is moved along the Z axis until the laser beam shines on the target's front surface.

4.5. Setting up the run parameters and options

Referring to the SEUSS window again, by clicking the Set Run Parameters button in the Users control group, a dialog box similar to that shown in Figure 11 will pop up. All the parameters within will be reset to the default values whenever the log file is changed (see *3.2.*).

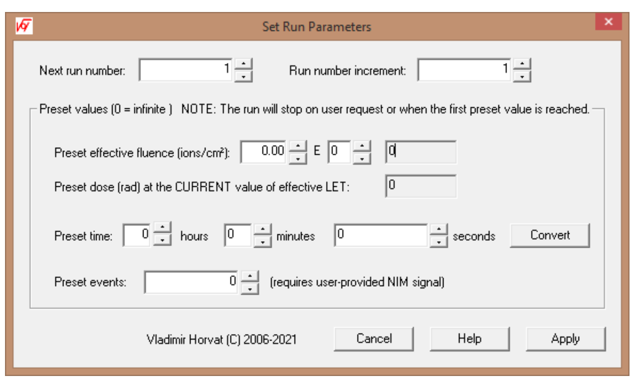

Figure 11. Example of the Set Run Parameters dialog box with the default values of the parameters.

4.5.1. Run numbering

The Next run number is the run number associated with the next successfully started run. It will be increased by the Run number increment after that run ends. Both parameters are initially set to 1, so that the runs are numbered 1, 2, 3, 4, ... *etc*. However, if so desired, these parameters can be changed at any time. For example, if at some point the Next run number is set to 12 and the

Run number increment is set to 3, the runs that follow will be numbered 12, 15, 18, 21, ... *etc*. Note that run numbers can be re-used. SEUSS does not check whether a run number was used previously.

4.5.2. Preset effective fluence and preset dose

Most users want their run to stop automatically when effective fluence reaches certain preset value. In the Set Run Parameters dialog box this preset value is entered by specifying the associated power of ten and its multiplier. The adjacent read-only box displays the preset effective fluence value in the standard format.

Accumulated dose is related to fluence and LET (but not to angle of incidence), and its preset value is displayed below the preset effective fluence, also in a read-only box. The preset dose value cannot be entered directly. Instead, the preset effective fluence value must be modified until the desired preset dose value is displayed.

4.5.3. Preset time and preset number of events

Running for a preset amount of time is a seldom-used and seldom-justified option, but it is available nevertheless. The preset time can be entered as any combination of hours, minutes and seconds. This combination can be converted to seconds-only by clicking the Convert button. If the Convert button is clicked again, the preset time will be converted to the standard HH:MM:SS format. To convert the preset time format back to seconds-only, click the Convert button one more time.

Users at our facility may want to provide a TTL or NIM pulse to the SEUSS hardware to mark an event of some kind. SEUSS software can then be set to end the run after a preset number of pulses (events) are detected.

4.5.4. Effects of preset values on the run in progress

If a preset value is zero, it will have no effect on the run.

If a non-zero preset value is specified for one quantity (effective fluence / dose, time, or the number of events), the run will be suspended as soon as that preset value is reached. A suspended run may be continued or it can be ended. If the run is ended, the same preset value will apply to the next run (unless the presets are changed in the meantime). If the run is continued, the preset value will have no effect on the run and the run will have to be suspended on demand.

If non-zero preset values are specified for more than one quantity (effective fluence / dose, time, and/or the number of events), the run will be suspended as soon as the first one of them is reached. If the run is ended, the same presets will apply to the next run (unless they are changed in the meantime). If the run is continued, none of the preset values will have any effect on the run and the run will have to be suspended on demand.

4.5.5. Run options

By clicking the Set Options button in the Users control group, a dialog box similar to that shown in Figure 12 will pop up. All the parameters within are reset to the default values whenever the log file is changed (see *3.2.*). The default values of the parameters are suitable for most users and should not be changed unless the effect of the change is well understood and desired.

One option that is used frequently while running at a low flux is Put detector counts in run files. When this is set as a preference, detector counts that are normally displayed once every second on the screen in the Beam characteristics group during a run, will also be recorded in the run file, along with the date/time stamp, uniformity, flux, and accumulated effective fluence. This will be preceded by the formulas used to calculate the flux and the accumulated effective fluence and followed by the regular content of a run file.

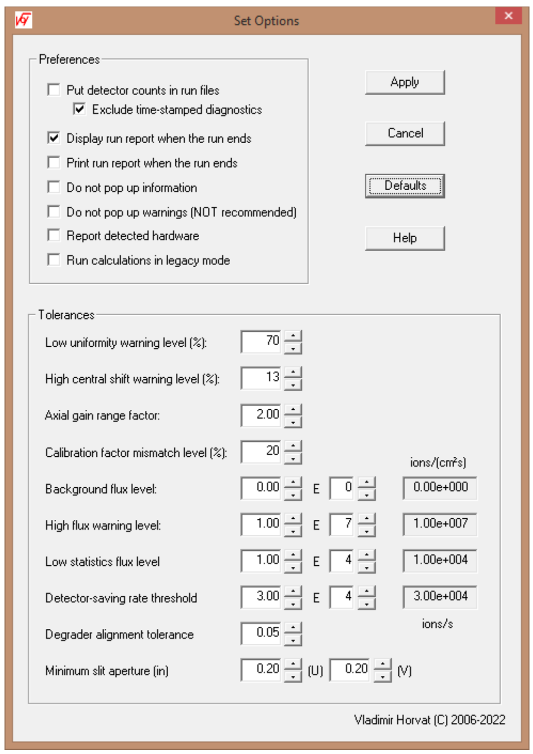

Figure 12. Example of the Set Options dialog box with the default values of the parameters.

4.6. Monitoring of the beam profile and flux

4.6.1. Configuration of the particle detectors

The beam profile is measured using five scintillation detectors with 0.1 cm^2 cross-sectional areas of their apertures. They are located slightly upstream from the target location. For all practical purposes their efficiency for counting incident protons and heavier ions is 100%. Located between the detectors and the target is a shutter (referred to as the downstream shutter, or S2) that normally blocks the ion beam, *i.e.*, prevents the ions from reaching the DUT.

Four of the scintillation detectors are permanently positioned at the vertices of a 2.3" × 2.3" square centered around and perpendicular to the beam axis, with horizontal and vertical sides. Based on their location, these detectors / ion counters are referred to as top left (TL), top right

(TR), bottom left (BL) and bottom right (BR), as viewed looking downstream. Collectively, they a referred to as the outer detectors.

The fifth detector, referred to as the central detector (or central ion counter, CIC), is tied to the upstream side of S2. When no run is in progress S2 is closed and CIC is positioned on the beam axis. During a run S2 is open and CIC is taken out of the way of the beam.

4.6.2. Uniformity and central shift

The outer detectors are set to count the incident ions continuously. At the end of each second the numbers of ions counted by the detectors during that second (n_{TL}, n_{TR}, n_{BL}, and n_{BR}) are displayed accordingly in the Beam characteristics group. Ideally, these four numbers should agree with each other within the expected statistical uncertainties. The quality of this agreement (disregarding statistical uncertainties) is conveniently expressed in terms of *beam uniformity*, which is displayed in the same group. It is calculated as $100/(1+n_r/n_m)$, where $4n_m=n_{TL}+n_{TR}+n_{BL}+n_{BR}$ and $3n_r^2=(n_{TL}-n_m)^2+(n_{TR}-n_m)^2+(n_{BL}-n_m)^2+(n_{BR}-n_m)^2$. Its value can range from 33% (when $n_{TL}>0$ and $n_{TR}=n_{BL}=n_{BR}=0$) to 100 % (when $n_{TL}=n_{TR}=n_{BL}=n_{BR}$). Note that the more relevant quantity is the *overall uniformity*, which is reported at the end of a run. It is calculated the same way as the beam uniformity, except that the detector counts are accumulated over the entire duration of the run. For most purposes the overall uniformity values of 90 % and above are considered good, while those between 80 % and 89 % are considered acceptable.

Central shift is another parameter that measures the agreement between the counts from the outer detectors, also displayed in the Beam characteristics group. It is calculated as $100\times[(n_{TL}+n_{BL}-n_{TR}-n_{BR})^2+(n_{TL}+n_{TR}-n_{BL}-n_{BR})^2]^{1/2}/[8n_m]^{1/2}$. It ranges in value from 0 (when $n_{TL}=n_{TR}=n_{BL}=n_{BR}$) to 100 % when $n_{TL}>0$ and $n_{TR}=n_{BL}=n_{BR}=0$. For most purposes the values of central shift below 14 % are considered acceptable.

4.6.3. Axial gain and calibration factor

The central detector is positioned to continuously count ions at the beam axis when no run is in progress. At the end of each second the number of ions counted by the detector during that second is displayed in the Beam characteristics group. Ideally, this number should agree with those reported by the outer detectors, within the expected statistical uncertainties. The quality of this agreement (disregarding statistical uncertainties) is conveniently expressed in terms of *axial gain*, which is displayed in the same group. It is calculated as n_{CIC}/n_m. Note that the more relevant quantity is the *calibration factor*, which is also displayed and is calculated the same way as the axial gain, but based on cumulative detector counts that all exceed 10,000 (since the last time the SEUSS window was opened or since the last calibration factor calculation). Its value should be close to 1, but any value between 0.5 and 2 is acceptable in most cases, especially if the device under test is much smaller in size than the separation between the outer detectors.

When the beam flux is low (lower than 1E4 ions/cm^{2}s), it takes a considerable amount of time for the detectors to count at least 10,000 events each, at which point the calibration factor value is updated. This is no longer a problem once the axial gain is updated and remains stable. However, average value of the axial gain may change over time (gradually or suddenly) for various reasons, most often due to changes in the beam optics, attenuator settings, or degrader settings. When the values of axial gain (measured and displayed once every second) are significantly and consistently higher or lower than the calibration factor value, the calibration factor should be measured on demand before starting the next run. That can be done by clicking the Measure button in the User controls group. This measurement stops automatically when relative accuracy of the measured calibration factor becomes better than 1 %. The measurement can be stopped early if so desired, based on the current accuracy displayed in the Status window of the Beam characteristics group. This is done by clicking the Stop button that became visible when the measurement started.

When the measurement stops for any reason, the user will have an option to set and lock the measured value of the calibration factor, so that it is no longer recalculated automatically and it will be up to the user to determine if or when an update is needed.

Any value of the calibration factor can be set and locked by entering it into the dedicated box in the User controls group and clicking the adjacent Set button. The Lock box will be checked automatically regardless of its previous status. While the calibration factor value is locked, it will not be recalculated automatically.

Whenever the Lock box is checked, a closed padlock icon will be displayed next to the calibration factor in the Beam characteristics group to indicate that the calibration factor will not be updated automatically. The Lock box can be unchecked by the user at any time. It is recommended that this is done as soon as the flux starts consistently exceeding 1E4 ions/cm^{2}s.

During the measurement of the calibration factor the detector counts are accumulated and displayed as such. The values of uniformity, flux, and central shift displayed during the measurement are based on these cumulative counts, and so they are more reliable than the corresponding values displayed once every second while no run is in progress. Therefore, the calibration factor should be measured on demand whenever a check of uniformity, flux, and/or central shift are desired while the beam flux is low. When fluctuations in their values during the measurement become tolerable, the measurement should be stopped.

Note that during the measurement of the calibration factor the cumulative result is displayed in the Axial gain box, while the previously measured value of the calibration factor is displayed in the Calibration factor box enclosed in parentheses.

4.6.4. Flux, effective fluence and dose

During a run, the central detector is removed in order to let the beam reach the target. The axial gain is then set to zero and the calibration factor remains unchanged for the duration of the run. The box that is normally used to display the axial gain is then used to display the *accumulated dose*, while the box that is normally used to display the one-second-interval counts from the central detector is used to display the *accumulated effective fluence*. [Relative uncertainty of the effective fluence in % is $100\times(2.5/\text{fluence})^{0.5}$ for fluence expressed in ions/cm^2. The factor 2.5 accounts for aperture of our detectors (4×0.1 cm^2).]

Flux is also displayed in the Beam characteristics group. Its value is based on the measurements over one-second intervals and it is updated once every second. Note that the more relevant quantity is the *average flux*, which is contained in the report generated at the end of a run. It is calculated the same way, except that the detector counts are effectively averaged over the time during which the beam path was clear. Relative uncertainty of the average flux is listed in the run report as well.

The highest heavy-ion rate that can be reliably measured by our detectors and the associated hardware is 3E6 counts/s. Therefore, the highest heavy-ion flux that can be reliably measured is 3E7 ions/cm^{2}s. We recommend that the flux of heavy ions is kept below 1E7 ions/cm^{2}s. Also, when the flux is set to more than 1E5 ions/cm^{2}s, we ask the users to block the beam while they are not running, to avoid unnecessary deterioration of our detectors. Users can block the beam by clicking the Close S1 button or the Control Positioning button. In the former case they can get the beam back by clicking the Open S1 button. In the latter case they have to click the Exit button to close the Control Positioning dialog box and then call the operator in the Control Room to restore the beam. Set Options dialog box can be used to instruct SEUSS to automatically open the Control Positioning dialog box as soon as a run ends and to close S1 after 30 seconds of idle time at a detector counting rate that exceeds the specified *Detector-saving rate threshold*. At a detector counting rate that varies around the threshold value, the 30-second counter is incremented by 1 each second when the rate is above the threshold and decremented by 1 each second when the rate is below the threshold.

4.7. Controlling target exposure by the beam of ions

4.7.1. Starting the irradiation

To prepare for the irradiation of your device click the Run... button in the User controls group. Note that irradiation will not start immediately. Before that happens, SEUSS may report any problems that could affect the run. You will have an option to postpone the run, so you can take care of the problem, or to run anyway. The final prompt will be Click OK to start run #xxx., where xxx stands for the number that will be assigned to the run after it starts. The beam path will be clear shortly after you click OK at this prompt.

At the start of the run the beam path is controlled by two mechanical shutters: the upstream shutter S1 and the downstream shutter S2. Shutter S1 is standalone and somewhat faster than S2, since S2 has the central detector and the beam-view camera attached to it. Before the irradiation S1 is open, while S2 is closed. When a run is about to start, S1 closes. When S1 is fully closed (thus blocking the beam path), S2 opens. When S2 is fully open, the Run start time is recorded, a +5 V DC level (the BEAM ON INDICATOR) is set at the designated output on the patch panel (both in the Cave and in the Data Room) and then S1 opens to clear the beam path.

4.7.2. Blocking and unblocking the beam temporarily during a run

During a run the beam can be temporarily blocked at any time by closing shutter S1 using the Close S1 button in the Cyclotron operator controls group. The beam can then be unblocked using Open S1 button located in the same group. Note that one of these two buttons is always available, depending on the current status of S1. It takes about the same amount of time to close or open S1. Do NOT use S2 to temporarily block the beam because S2 does not prevent the beam from reaching the outer detectors, which means that SEUSS will continue to accumulate the fluence/dose as if the beam were not blocked.

Another option to temporarily stop irradiation during a run requires bypassing SEUSS and interacting directly with the cyclotron's RF controls to detune the beam. To use this option the users must request it at the time they request their beam time. Also, during the run, the users must provide a +5 V DC level when they want the beam to go away, and 0 V DC or a short to the ground when they want the beam back. While this is doable by means of a switch and a battery, such an approach has no advantage compared to the regular method described above. Ideally, the two DC levels should be provided by a device under user's computer control, as a timely response to some kind of signal received from the DUT.

Note that the BEAM ON INDICATOR is *not* affected when the beam is temporarily blocked and unblocked using either of the methods described above. Furthermore, time while the beam is blocked will count as Dead time, provided that the flux measured during that time is at or below the *background flux level*. The background flux level is set in Set Options and its default value is zero.

4.7.3. Suspending and ending a run

A run can be suspended at any time by clicking the STOP button, which is visible and available during the run. Virtually any key on the keyboard can be pressed to produce the same effect, as long as the cursor is within the box located at the bottom right corner of the Beam characteristics group. Note that this box will become visible and available when the run starts, and the cursor will be placed there at that time.

A run is also suspended when the first one of the preset quantity values is reached (effective fluence, time, or the number of user-provided signals).

When a run is suspended, S1 closes and the BEAM ON INDICATOR is set to 0 V DC level. A pop-up window shows the accumulated effective fluence, dose, elapsed live time, and the measured peak flux value. User will be prompted to continue the run ignoring all preset values, or to end the run. If the former option is chosen, the BEAM ON INDICATOR is set back to +5 V DC level, S1 opens and the run continues. If the latter option is chosen, S2 closes. Once S2 is completely closed, the Run end time is recorded and S1 opens. When a run ends, NOTEPAD™ text editor (supplied with Microsoft Windows™) starts and opens a copy of the run report file, assuming that this preference is not unselected in the Set Options dialog box.

A run report includes the Run start date and time and when the Run end date and time. The difference between the two is reported as Duration of the run. Also reported is the Live time (s), which is the sum of time intervals during the run in which the measured flux was above the background flux level. The background flux level is set in Set Options and its default value is zero. The sum of time intervals during the run in which the measured flux was at or below the background flux level is reported as Dead time (s). Since Duration of the run includes Live time (s), Dead time (s), and the time it took the user to react to the run-suspended prompt, Duration of the run is almost always greater (and never less) than the sum of Live time (s) and Dead time (s). Any contribution to the Dead time (s) will also be date/time-stamped and recorded in the log file.

4.7.4. Real-time monitoring of flux and effective fluence by the users during a run

Positive TTL signals from the top left (TL) ion counter are provided to the users in the Data Room and in the Cave while the BEAM ON INDICATOR is at +5 V DC. These signals can be used to monitor flux and accumulated effective fluence in real time. One run should be used for calibration while the DUTs are placed out of the beam path. At the end of this run the effective fluence reported by SEUSS should be divided by the measured total number of TL signals, so that in the future runs the accumulated effective fluence in real time can be obtained by multiplying this result with the accumulated number of TL signals.

4.8. User comments and reports

A box in the top right corner of User controls group contains a list indicating the ASCII files whose content can be viewed after clicking the corresponding item, either directly or in a dialog box that will pop up. A selected file will be opened by NOTEPAD™ text editor as a copy of the original. It is not possible to edit the original files directly using SEUSS, except that a comment line can be added to the log file and/or to the last run file. This can be done by entering the comment in the designated box in the User controls group and clicking To Log File and/or To Run File, respectively. If To Screen is clicked, the entered comment will be permanently displayed in the designated box until a blank comment is entered and sent To Screen.

User files item function is to allow access to the contents of all the run files. From the View User File dialog box that opens (similar to the one shown in Figure 13), a copy of any individual run report can be viewed by clicking the corresponding file name in the displayed list and then clicking the View Text button.

Run summary item function is to prepare and open a copy of the report that contains the data from all previous runs organized like a spreadsheet.

Layer details item function is to open a copy of the report that contains detailed annotated list of parameters for each defined layer (see *4.3.4.*).

Log file item function is to open a copy of the log file, which contains time-stamped records of actions taken by the user while running SEUSS and the corresponding outcomes.

User options item function is to open an ASCII file containing the list of preferences and tolerances that are set by default or chosen using the Set Options dialog box.

Current settings item function is to open a file that contains a list of defined operating conditions (described in **4.3.**).

Range table item function is to open a file that lists specific properties of the selected beam inside the substrate.

4.9. Obtaining copies of user run files

At our facility user run files are stored in the Users subfolder of the SEUSS start folder. Users are discouraged from accessing these files directly in order to prevent accidental deletion or modification of files belonging to another user or those that SEUSS is set to access and needs them in order to run without crashing. However, users can copy the files from Users folder to drive E and then move them from drive E to their USB flash drive.

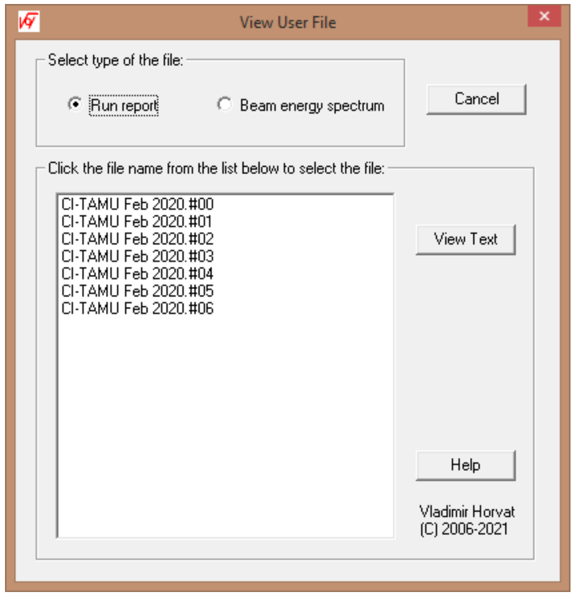

Figure 13. Example of the View User File dialog box.

Copying of user files to drive E can be initiated by double-clicking the Transfer user data icon located on the SEUSS computer desktop. The same is accomplished every time the log file name is changed. The USB port available for the users' flash drive is located on or near the SEUSS monitor inside the Data Room. Note some models of USB flash drive may not be recognized by the SEUSS computer. Alternatively, your files can be emailed to you on your request.

For users who are granted on-line access to the SEUSS computer for automated downloading of run data in real time, data from the most-recently finished run are available in JSON format in file named Run_Data.json. This file is located in the SEUSS program folder. It is created when a run ends and deleted when a new run starts, so that it does not exist while a run is in progress.

4.10. Closing the SEUSS window

With just a few exceptions, only one window or dialog box is open while SEUSS is running, depending on the context. Consequently, when a new window opens, the parent window closes and when a window closes, its parent window opens. A window should be closed only by using the buttons provided for that purpose. Closing of some windows using the white X mark in a red box located in their top right corner is disabled.

To close the SEUSS window, check the Enable box in the Cyclotron operator controls group, then click Exit Program.

4.11. Unchecking the Enable box

In the final stage of beam tuning at our facility the operator needs to look at the SEUSS window in order to adjust the beam-optics settings. At that point the operator will check the Enable box in the Cyclotron operator controls group to disable the buttons in the User controls group and let the users know that beam-tuning is in its final stage, so that they should not attempt to use

SEUSS for any other purpose. When the beam is ready, the operator will uncheck the Enable box. At that point a message will pop up indicating that "The beam is now available for radiation testing". The operator will then try to convey that message to the users using a phone or an intercom. If the users do not respond, the message box will be left on the screen. Otherwise, the users or the operator may click OK to close the message box. The same message pops up every time the Enable box is unchecked, but in any other circumstances it should be ignored.